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Bermudagrass management in the Southern Piedmont USA V: Gastrointestinal parasite control in cattle

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Abstract

Parasite-free pastures would improve cattle health and performance, resulting in possible economic return to producers. Our objective was to determine the effect of a single series of anthelmintic treatment of steers prior to stocking on Coastal bermudagrass pastures, during five consecutive summers, on the parasite burden in cattle. The site for this experiment had been conventionally cropped for several decades, with no exposure to cattle, and would be expected to be relatively free of nematode larvae. The experimental design was a randomized complete block (landscape features) with a split plot arrangement of treatments where main plots were pasture fertilization treatments (mineral, clover plus mineral, and broiler litter) and split plots were low and high forage mass. Anthelmintic treatment included pour-on ivermectin on day −21, albendazole on day −7, and injectable ivermectin 48 h prior to stocking of pastures, with the cattle remaining in drylot during the 48-h period prior to being placed on the experimental paddocks. All steers received only one series of treatments during any given year. Yearling Angus steers (*Bos taurus*) were managed in a put-and-take grazing system with three "tester" steers assigned to each paddock and "grazer" steers added or removed at 28-day intervals. From 1994 to 1998, steers grazed the paddocks for a 140-day period from mid May until early October each year. Fecal samples for worm egg counts

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were obtained on day 0 and at 28-day intervals, thereafter. On all sampling days after day 0, samples were obtained only from tester animals. Over the 5-year period, the mean eggs per gram of feces (epg) gradually increased from 0 (following treatment) to a mean of 2.2 (range from 0.7 to 3.0) by the end of the grazing season (the last sampling date) in October. Although the epg were not zero, they were below threshold levels that would allow development of a parasite burden in cattle. In traditional management systems, cattle graze parasite-contaminated pastures; therefore, parasites negatively impact growth and productivity throughout the entire grazing period. Periodic anthelmintic treatments simply give a temporary reprieve from those parasitic infections. Conceptually, using the current grazing system, it should be possible to maintain these pastures in a parasite-free status indefinitely; however, from a drug resistance perspective, it would be most applicable in sod-based rotation systems where cattle graze from two to five years before land is returned to row-crops. By removing the effect of parasites, cattle can grow without the physiological constraints that gastro-intestinal parasites place on appetite, digestion, nutrient utilization, and general well being.

Keywords: Cattle–nematoda; Control methods-nematoda; Parasite free; Sod-based crop rotations; Pasture; Bermudagrass

1. Introduction

Sustainable production systems that maintain or enhance our natural resource base while reducing our dependency on external chemical inputs including pesticides are needed (Lockeretz, 1988; Parr et al., 1990). Gastrointestinal parasites are a major constraint to animal health, productivity, and profitability in grazing livestock production systems (Fox, 1997). It has generally been assumed that parasite infections in grazing animals are inevitable; therefore, treatment and control programs have been aimed simply at reducing rather than eliminating the effect of parasites. However, this assumption may not be true. Based on a number of reviews on epidemiology of gastrointestinal nematodes (GIN) (Thomas, 1982; Williams, 1986a), it could be assumed that cropland with no exposure to cattle for several years would have relatively few infective nematode larvae. If these croplands were converted to pasture and cattle were treated with anthelmintics prior to placing animals on these pastures, theoretically, it should be possible to maintain the pastures in a parasite-free state or below threshold levels. This concept is similar to that of the "safe pasture" preventative control system that combines anthelmintic treatment with management (Michel, 1976; Brunsdon, 1980; Morley and Donald, 1980; Williams, 1986b). In the Southern Piedmont Major Land Resource Area (MLRA) of the United States, there has been ongoing conversion of cropland to managed pasture (Census of Agriculture, 1992, 1997). In the Southern Coastal Plain MLRA, this same trend has been occurring. Plus, there is a trend to move from continuous row-crop systems to sod-based rotation systems in order to increase crop yields, reduce the use of pesticides, and ultimately improve farm income (Baldwin et al., 2003; Hartzog and Balkcom, 2003; Marois and Wright, 2003). These rotation systems incorporate cattle grazing for two to five years before going back to a row-crop. This conversion of continuously cropped land to a rotation that includes pasture provides an excellent opportunity to integrate anthelmintic treatment with management to provide and maintain parasite-free pastures. It is well documented that stocking densities, coupled with the forage mass available for consumption, can impact the consumption of infective larvae (Ciordia et al., 1962), i.e., the less forage mass available for consumption or the more closely pastures are grazed, the greater the likelihood of consumption of infective larvae. In tall fescue pastures fertilized either with mineral fertilizer or broiler litter and grazed by cows and calves, it was concluded that forage mass available for consumption accounted for differences in cattle parasite burdens rather than the use of broiler litter as a pasture fertilizer (Ciordia et al., 1977).

Our objective was to determine if newly established pastures could be maintained parasite-free by judicious anthelmintic treatment of cattle prior to stocking. We also wanted to determine whether fertilization regime and forage mass available for consumption would affect parasite levels.

2. Materials and methods

2.1. Site characteristics

A 15-ha upland field (33°22′N, 83°24′W) in the Greenbrier Creek subwatershed of the Oconee River watershed near Farmington, GA, had previously been conventionally cultivated with cotton (*Gossypium hirsutum* L.), sorghum [*Sorghum bicolor* (L.) Moench] soybean [*Glycine max* (L.) Merr.], and wheat (*Triticum aestivum* L.) for several decades prior to grassland establishment by sprigging of Coastal bermudagrass [*Cynodon dactylon* (L.) Pers.] in 1991. Mean annual temperature is 16.5 °C, rainfall is 1250 mm, and potential evaporation is 1560 mm, and elevation is 205–215 m above sea level.

2.2. Experimental design

The experimental design was a randomized complete block with treatments in a split plot arrangement in each of three blocks, which were delineated by landscape feature (i.e., slight, moderate, and severe erosion classes). Main plots were pasture fertilization treatments ($n = 3$) and split plots were grazing at two different forage masses ($n = 2$). Individual paddocks ranged from .65 to .75 ha. Paddock shape minimized runoff contamination among paddocks and an animal handling and service alley followed the top of the landscape. Each paddock contained a 3 m × 4 m shade, a mineral feeder, and a water trough placed in a 15 m line near the top of the landscape.

Fertilizer was applied to a achieve a target of 200 kg N ha^{-1} yr^{-1} in each of three manners: (a) mineral only as NH_4NO_3 broadcast in split applications in May and July, (b) crimson clover (*Trifolium incarnatum* L.) cover crop plus supplemental mineral fertilizer with one-half of the N assumed fixed by clover biomass and the other half as NH_4NO_3 broadcast in July, and (c) broiler litter broadcast in split applications in May and July. Phosphorus and K applications varied among treatments because excess P and K were applied with broiler litter (124 ± 40 kg P ha^{-1} yr^{-1} and 167 ± 48 kg K ha^{-1} yr^{-1}) to meet N requirements, while diammonium phosphate and potash were applied based on soil test recommendations (16 ± 11 kg P ha^{-1} yr^{-1} and 52 ± 41 kg K ha^{-1} yr^{-1} for inorganic fertilizer and 23 ± 20 kg P ha^{-1} yr^{-1} and 55 ± 41 kg K ha^{-1} yr^{-1} for crimson clover cover crop plus supplemental inorganic fertilizer). Crimson clover was directly drilled in clover treatments at 10 kg ha^{-1} in October each year. All paddocks were mowed in late April and residue allowed to decompose [i.e., clover biomass in clover plus mineral fertilizer treatment and winter annual weeds in other treatments].

Forage mass treatments were (a) high forage mass (target forage mass of 3000 kg ha^{-1}) and (b) low forage mass (target forage mass of 1500 kg ha^{-1}).

2.3. Cattle

Yearling Angus steers (*Bos taurus*) with initial weights of about 250 kg (Table 1) were allocated to the paddocks beginning in mid May each year, except in 1994 when paddocks were stocked in mid July due to repairs to infrastructure following a tornado. Cattle grazed paddocks until early October each year (140 days). Steers were managed with a put-and-take grazing system with three ‘‘tester’’ steers assigned to each paddock and ‘‘grazer’’ steers added or removed, based on forage mass, at 28-day intervals except on two occasions at 14-day intervals due to extended drought.

Tester steers were randomly selected from three groups of 18 steers; one group closest to the mean weight, a second group immediately heavier and a third group immediately lighter than the mean weight. All cattle weights were from shrunk body condition (i.e., 16 h without water). Grazer steers were assigned in a similar manner from the remaining pool of animals, i.e., alternating higher and lower weights closest to the mean. Grazer steers not allocated to paddocks grazed an adjacent parasite-free pasture. Stocking density for each paddock and grazing period was computed by assuming daily forage intake would be 2.2% of body weight. Forage mass within each paddock was estimated prior to each stocking period from four to nine areas (.25 m^2) clipped to ground level. Average annual forage mass is presented in Table 2.

2.4. Anthelmintic treatment

Prior to stocking each year, all steers received the following treatment: pour-on ivermectin on day −21, albendazole on day −7, and injectable ivermectin 48 h prior to stocking of pastures, with the cattle remaining in drylot during the 48-h period. No additional anthelmintic treatments were administered.

Table 1
Initial tester steer weights

Year	*N*	Weight (kg)	S.D.	Minimum	Maximum
1994	51	261	14.6	227	286
1995	54	273	15.8	243	313
1996	54	258	13.8	227	286
1997	54	245	18.7	197	279
1998	54	247	12.9	218	272

Table 2
Mean above-ground forage mass (mg ha^{-1}) by fertilizer treatment and grazing intensity

Year	Fertilizer treatment			Grazing intensity	
	Clover	Litter	Mineral	High	Low
1994	5.3	5.7	6.2	4.3	7.2
1995	3.8	3.5	3.9	2.6	4.8
1996	3.4	3.3	3.3	2.2	4.5
1997	3.7	3.4	4.0	2.3	5.1
1998	2.2	2.4	2.6	1.5	3.3
Mean	3.7 a	3.7 a	4.0 b	2.6 c	5.0 d

Values with different letters (a, b) across fertilizer treatments differ, $P < .05$. Year × fertilizer treatment interaction was significant, $P < .0001$. Values with different letters (c, d) across grazing intensity differ, $P < .05$. Year × grazing intensity interaction was significant, $P < .0001$.

2.5. Fecal sampling and analyses

Rectal fecal samples were obtained on day −21 (in years 1994, 1997 and 1998) and at the beginning and end of each 28-day stocking period, thereafter. Except for samples at day −21, fecal samples were from tester steers only. A modification of Stoll's flotation–centrifugation technique with a sensitivity of 0.5 eggs per gram (epg) was used to determine the number of nematode eggs present (Stoll, 1930).

On the final sampling in October 1998, a total of 50 g of feces was pooled from two or three nematode positive fecal samples per paddock for cultivation of bovine trichostrongyle larvae. Fecal cultures were performed within 48 h of fecal collection by adding an equal volume of vermiculite to the feces, mixing well and then adding a small amount of additional tap water to moisten the samples (Steffan et al., 1989). Fecal cultures were mixed with a wooden applicator stick every 2–3 days and stored at room temperature to permit the development of L_3 larvae (infective stage). At the end of 14 days, L_3 larvae were recovered using the Baermann technique, stained with lugols iodine and identified to genus (M.A.F.F., 1977).

2.6. Statistical analyses

Because fecal worm egg counts increased during the grazing season and were greatest at the last sampling date of each grazing season, only data from the October sampling were statistically analyzed for treatment differences. Fecal epg were transformed by calculating base 10 logarithm (total epg + 1) to obtain homogeneity of variance. Paddock epg were analyzed as a randomized complete block design that included random and fixed effects with repeated measures (years). Block was considered as a random effect while year, fertilizer, and forage mass or grazing intensity were fixed effects. Statistical analyses were calculated using the Mixed Procedure of SAS (Littell et al., 1996).

Nematode L_3 identified from fecal cultures were measured by paddock and each nematode genera was calculated as the percent of the total L_3 larvae identified on that paddock. For analysis of variance purposes, these proportions were transformed to arc sine angles (Snedecor and Cochran, 1980). These angles for each nematode genera were analyzed by the Mixed Procedure of SAS as described for fecal epg. Genera composition means were reported as the percentages.

3. Results

3.1. Steer performance

Average daily gain (ADG) of tester steers across the five years were .84, .72, and .76 kg day^{-1} for steers grazing the clover, broiler litter, and mineral fertilization treatments, respectively. Steers grazing the clover treatment had higher ($P < .05$) ADG than those on either of the other treatments. There is no obvious explanation for these differences in ADG. Steers grazed at the low forage mass (high intensity) had lower ($P < .05$) ADG (.67 kg day^{-1} versus .88 kg day^{-1}) than those grazed at the high forage mass (low intensity). Steer stocking rates per ha were higher ($P < .05$) for the mineral fertilizer treatment (8.11 steers ha^{-1}) than either the clover or broiler litter treatments (6.59 and 6.96 steers ha^{-1}, respectively). In terms of production per ha, the mineral fertilizer treatment resulted in higher ($P < .05$) kg steer gain per ha (716) than the broiler litter treatment (594) but similar gain compared to the clover treatment (641).

3.2. Fecal egg counts

Pre-treatment fecal epg illustrates that the steers were parasitized prior to anthelmintic treatment (Table 3). Fecal egg counts for the last sampling date in each year and overall are presented in Table 4. As shown in Figs. 1 and 2, the epg were highest at the end of the grazing season in October.

3.3. Fecal culture/generic composition

Statistical analyses of fecal culture results (Table 5) revealed that there were no treatment differences in average percent of L_3 larvae for each genera present. The genera with the highest percentages were *Hemonchus* and *Cooperia* spp., which are the common

Table 3
Mean pre-treatment fecal egg counts (eggs/gram or epg)

Year	*N*[a]	Total epg	S.D.
1994	100	220.1	257.5
1995	ND[b]	ND	ND
1996	ND	ND	ND
1997	102	82.0	66.0
1998	54	31.3	27.7
Mean		125.2	183.8

[a] *N*, number of steers sampled.
[b] ND, not determined.

Table 4
Mean fecal egg counts (eggs/gram) for October by fertilizer treatment and grazing intensity

Year	Fertilizer treatment			Grazing intensity	
	Clover	Litter	Mineral	High	Low
1994	.7	4.1	6.1	2.6	4.7
1995	0	.7	.4	.7	.1
1996	.9	4.2	4.0	3.1	3.0
1997	.4	3.6	2.4	.6	.7
1998	1.3	2.6	1.7	.8	2.9
Mean	.7 a	3.0 b	2.9 b	1.6 c	2.9 d

Values with different letters (a, b) across nitrogen treatments differ, $P < .05$. Values with different letters (c, d) across grazing intensity differ, $P < .05$. Year × grazing intensity interaction was significant, $P < .0251$.

warm weather gastrointestinal nematode species found in Georgia cattle (Becklund, 1962; Porter, 1942). *Ostertagia* and *Cooperia oncophora* are often considered the most pathogenic species, but made up a low percentage of the total L_3 present. Since these parasites tend to be cool weather species, this result is not surprising. *Oesophagostomum* larvae were found only in animals grazing the clover treatment. No explanation for this is known.

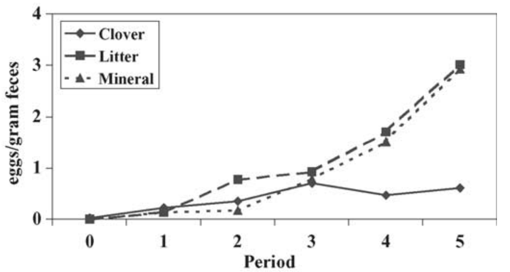

Fig. 1. Mean fecal eggs per gram of feces by 28-day period from mid May to early October, 1994–1998, for steers grazing each of the three pasture fertilization treatments (mineral as NH_4NO_3; crimson clover plus NH_4NO_3; and broiler litter).

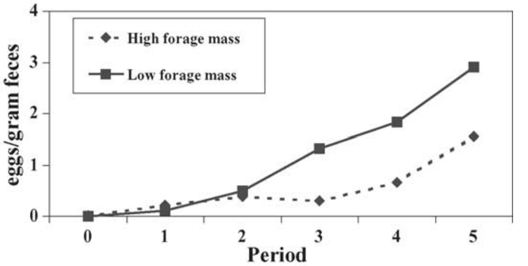

Fig. 2. Mean fecal eggs per gram of feces by 28-day period from mid May to early October, 1994–1998, for steers grazing at low forage mass or 1500 kg ha^{-1} (high intensity) and high forage mass or 3000 kg ha^{-1} (low intensity).

Table 5
Mean percent of nematode L_3 identified in feces of grazing steers, by fertilizer treatment and grazing intensity

Species	Fertilizer treatment			Grazing intensity	
	Clover	Litter	Mineral	High	Low
Haemonchus	63.2	68.2	67.3	66.3	66.1
Ostertagia	.7	1.9	1.5	1.9	.8
Cooperia oncophora	1.0	1.3	12.7	1.4	8.6
Cooperia spp.	11.1	28.3	18.5	19.2	19.4
Trichostrongylus	.2	.3	0	0	.4
Oesophagostomum	23.9	0	0	11.1	4.8

4. Discussion

Steer daily gains on Coastal bermudagrass in this study are very comparable and perhaps greater than those observed by researchers comparing performance of cattle on various hybrid bermudagrasses (Conrad et al., 1981; Utley et al., 1978) in regions where bermudagrass is better adapted than in the Southern Piedmont. This study was not designed to determine the impact of internal parasites on animal performance, and therefore, control groups of cattle managed similarly but without anthelmintic treatment were not included. However, steers of this age are known to be highly susceptible to gastrointestinal nematode infections and significant losses in ADG resulting from GIN infections have been documented on many occasions (Ballweber et al., 1997; Craig, 1999; Skogerboe et al., 2000). These data strongly suggest that at least a portion of these excellent daily gains could be attributed to the fact that the pastures were free of parasites.

Differences in ADG among fertilization treatments were observed, but there are no obvious reasons for this difference. Although forage production was not estimated, the available forage mass determined the number of steers on a paddock at any given time. Data revealed that the average number of steers per ha was higher on the mineral treatment than either of the other treatments. Because production per ha is a function of performance and the number of steers per ha, production per ha was higher on the mineral fertilizer treatment (716 kg) than the broiler litter treatment (594 kg) but similar to that of the clover treatment (641 kg).

Although there were statistically significant treatment differences in fecal epg, the very low average epg indicate that there are no biologically significant differences among treatments. We postulate that because fecal egg counts were very low they did not follow the general relationship between stocking density and forage mass that has been traditionally observed, i.e., the higher the stocking density or less forage mass, the greater the fecal egg counts.

Although the October epg were not zero, these low fecal egg counts suggest that epg throughout the grazing period were below threshold levels that would allow development of a significant parasite burden in cattle. The threshold levels that could allow for development of a parasite burden in the steers are unknown for conditions of this experiment, but because epg did not increase logarithmically, we can say that the epg observed in this study might be below those levels. A variety of factors including forage mass, cattle numbers and animal class could influence the threshold levels necessary to allow development of a parasite burden in the cattle. Consequently, under the conditions of this experiment, pastures were maintained in essentially a parasite-free condition for at least five years by simply prophylactically treating animals with anthelmintics prior to placing them on the parasite-free pastures. The therapeutic treatment prevented transport of nematode ova to the pastures, thus preventing environmental contamination with larvae. It is possible that some contamination of certain genera could have resulted from wildlife, most probably deer.

The sensitivity of detection used for performing fecal egg counts in this study was much greater than that used for normal diagnostics. If the more usual McMaster method had been used, every animal in this study over the 5-year period would have tested fecal-negative for gastrointestinal nematode ova on every test date. Over the 5-year period, mean epg at the end of the grazing period was 2.2; this level is approximately two orders of magnitude less than mean epg levels that one would expect under a more traditional management scheme. The treatment regimen used in this study was selected to ensure that cattle would enter the paddocks each spring in an essentially parasite-free state. Our more recent studies have demonstrated that this same effect can be achieved by a single dosing with two different anthelmintics given simultaneously on day -3.

A major concern with this strategy is the potential for selection of anthelmintic resistant worms. Maintaining high levels of refugia is recognized as the most important factor in preventing the development of resistance, and most new recommendations for nematode parasite control in livestock are based on the principle of maintaining adequate levels of refugia (Coles, 2002; van Wyk, 2001). In contrast, the treatment and management system used in our studies were specifically designed to minimize refugia. However, computer modeling suggests that treating animals with more than one drug at the same time (when resistance allele frequencies are low) will essentially prevent the development of resistance in nematode populations (Barnes et al., 1995). We, therefore, adopted a two-drug treatment scheme in this management system and have seen no evidence of resistance after 10 years of use (unpublished). This could be due to the rest periods, which allows the great majority of L_3 larvae present to die. Furthermore, small numbers of resistant worms that might infect these steers by October are taken with them to the feedlot where the worms will not spread or be transmitted to other animals. However, it is important to emphasize that if this management scheme is adopted by farmers, care must be taken to limit the potential for selection and spread of drug-resistant worms by proper adherence to treatment regimens and to rotations schedules utilizing both sod-based cattle and row-crop productions systems.

5. Implications and conclusions

Conceptually, using the current grazing and anthelmintic treatment regimen, it should be possible to maintain these pastures in a parasite-free status indefinitely. By removing the effect of parasites, cattle can grow without the physiological constraints that gastrointestinal parasites place on appetite, digestion, nutrient utilization, and general well being. In traditional management systems, cattle graze parasite-contaminated pastures; therefore, parasites negatively impact growth and productivity throughout the entire grazing period. Periodic anthelmintic treatments simply give a temporary reprieve to those parasitic infections. By using anthelmintic treatments in a prophylactic manner in combination with parasite-free pastures, we have demonstrated that the goal of essentially parasite-free grazing of cattle is achievable. This approach reduces the number of anthelmintic treatments required, and enhances animal productivity. It may have particular application in sod-based rotation systems where cattle are grazed for two to five years prior to returning to row-crop production.

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